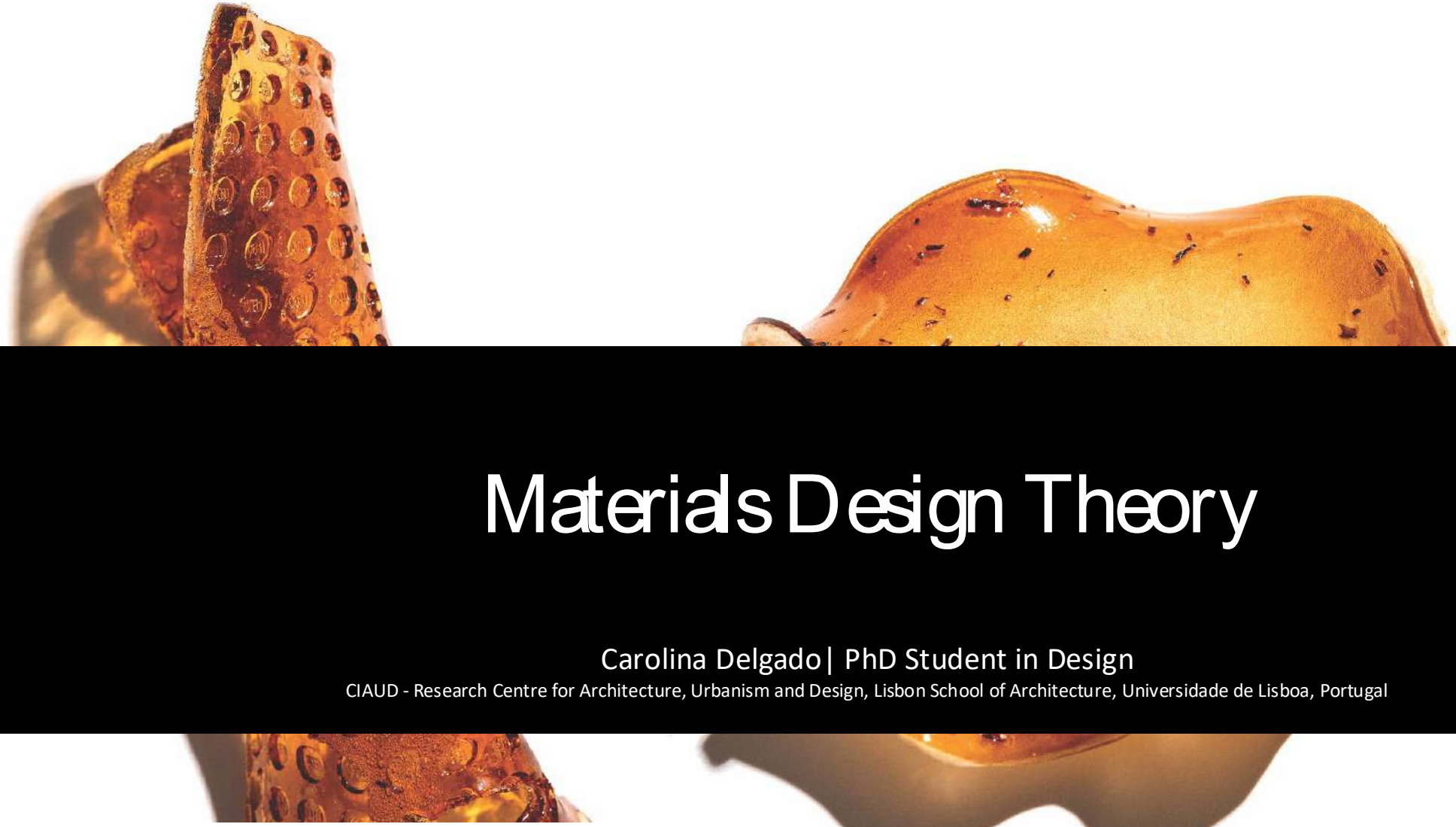


29th Oct. 2026

Materials Design Theory

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IFIMUP Institute of Physics for Advanced Materials, Nanotechnology and Photonics

fct Fundação para a Ciência e a Tecnologia

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2. A Short History of Plastics
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    1. Sources
    2. Bio-Materials Libraries
    3. Resources
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5. References



Introduction

Environmental, economic & social

(Brundtland Report, 1987; Desa, U.N., 2016)

Marine life

(Stasiškienė et al., 2022)

Human health

(Leslie et al., 2022; Ragusa et al., 2022)

Fig. 1: **Plastic in the ocean**, Istock photo

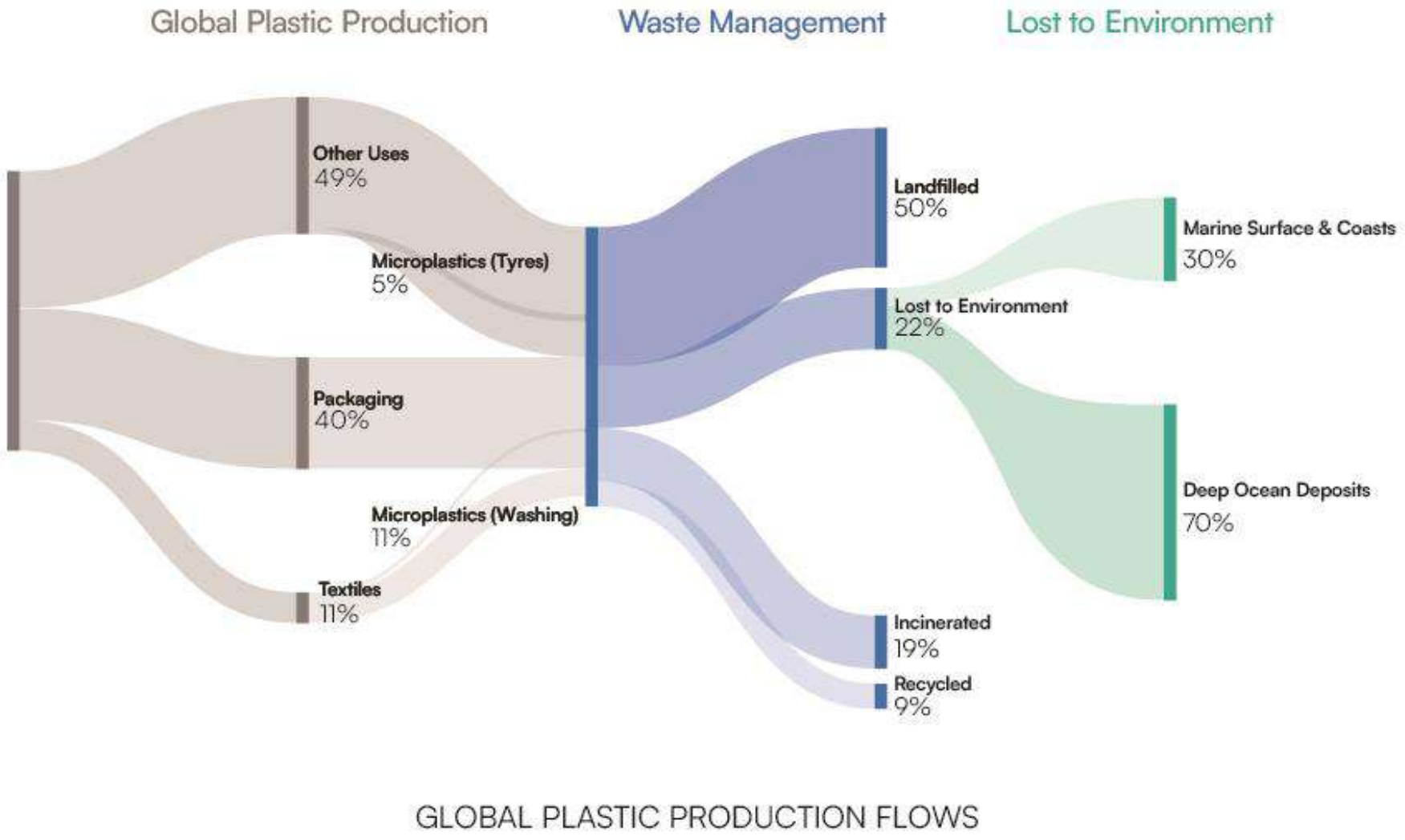


Fig. 2: **Economy from linear to circular Scheme** – Global plastic production flows - major use sectors, waste management, and marine accumulation, based UNEP (2009), OECD (2022), Carney Almroth et al., (2018), Salvador Cesa et al., (2017), Kole et al., (2017) and Redondo-Hasselerharm et al., (2018), 2026



Fig. 3: **Agenda 2030 for Sustainable Development** – UNITED NATIONS, Desa, U. (2016)

Circular Design

Design for circular economy

(Wastling et al., 2018)

Green Deal (European Commission, 2021)

Textile and packaging industries (Ellen MacArthur Foundation, 2017; Sandin & Peters, 2018)

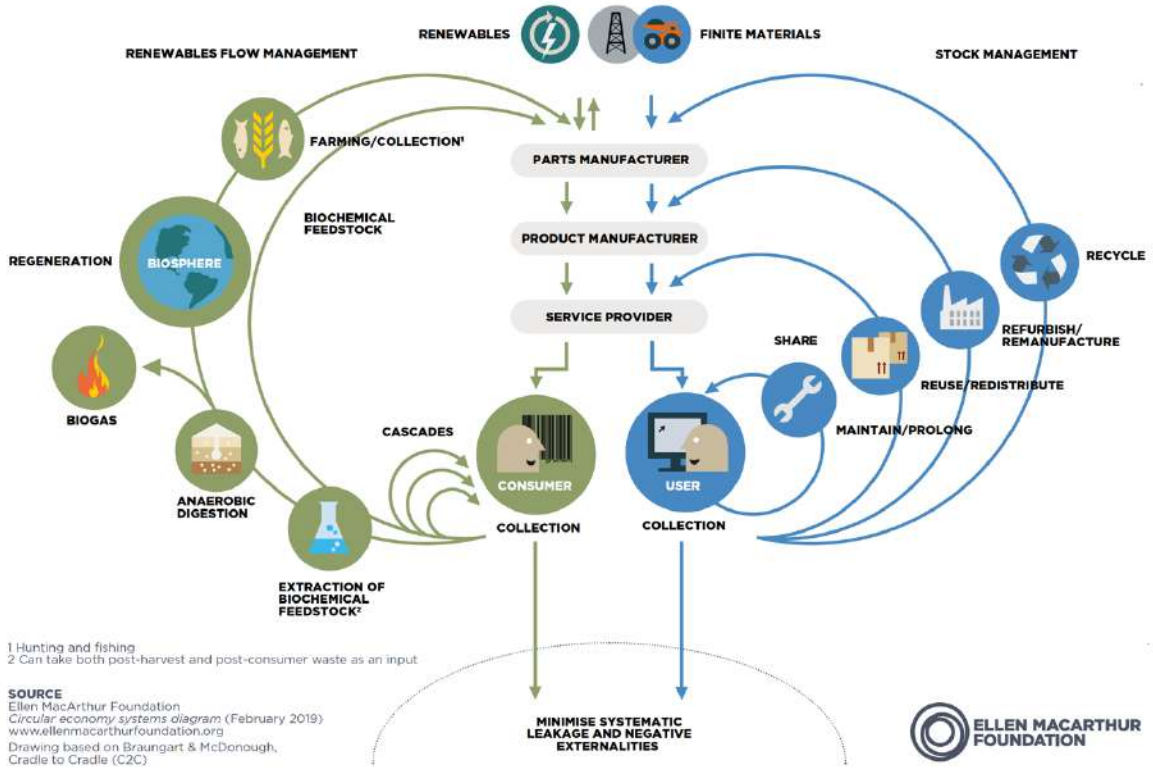


Fig. 4: **The Butterfly diagram: visualising the circular economy** – Ellen Macarthur Foundation (2019)

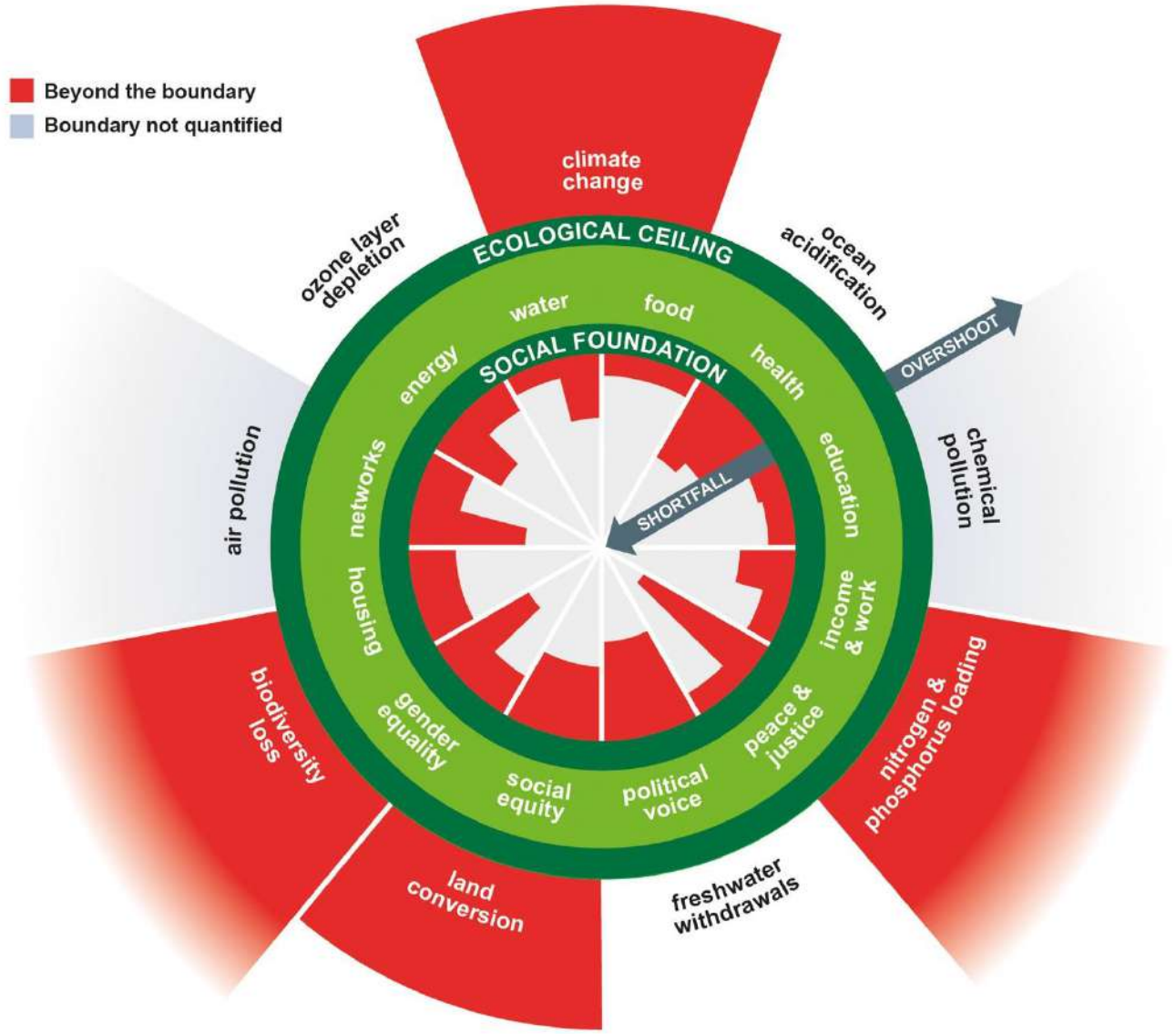


Fig. 5: **The Doughnut of Social and Planetary Boundaries** – Raworth (2017)

Planetary ceilings

Doughnut economy

(Kate Raworth, 2017)

A Short History of Plastic

Everything began with a remarkable effort to protect wildlife
(Siegle, 2018)

1855
Parkesine
the world's first plastic,
created by Alexander Parkes in Birmingham.
derived from cellulose, initially used for buttons, collars, and cuffs,

reducing dependence on natural materials like ivory and horn.

1863
Celluloid
the first thermoplastic
invented by John Wesley Hyatt in the U.S.

safer alternative to ivory, reducing the demand for elephant tusks and preserving wildlife

1907
Bakelite
the first synthetic thermosetting plastic,
invented by Leo Baekeland, can be heated, shaped, and cooled while maintaining its form.

durable resin is widely used in household goods, electronics & automobiles

1950s
Modern Polymerization
breakthroughs by Karl Ziegler and Giulio Natta
wins the Nobel Prize,
The discoveries lead to the development of modern plastics

(PE) polyethylene and
(PP) polypropylene,
lead to today's plastic industry.

(Devi et al., 2015; Siegle, 2018; Rasmussen, 2021)

Hemp ethanol and Plastic, Ford 1941

The Hemp Farming Act passed on December 2018, legalized hemp production in the USA. With the act, Ford and Dietzen's prototypes may yet help eradicate the fossil fuel-based auto industry and make transportation sustainable.

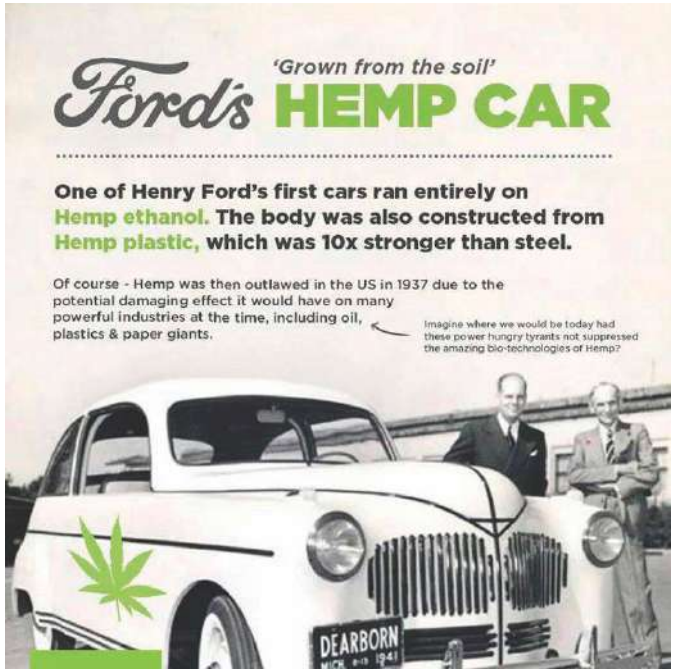


Fig. 6: **Hemp Ford Car**, 1941, retrieved from http://in5d.com/henry-fords-suppressed-hemp-car/



Fig. 7: **Jay Leno´s hemp car**, 2020, retrieved from https://themeaningofwater.com/2020/10/03/henry-fords-hemp-cars/

What are Plastics?

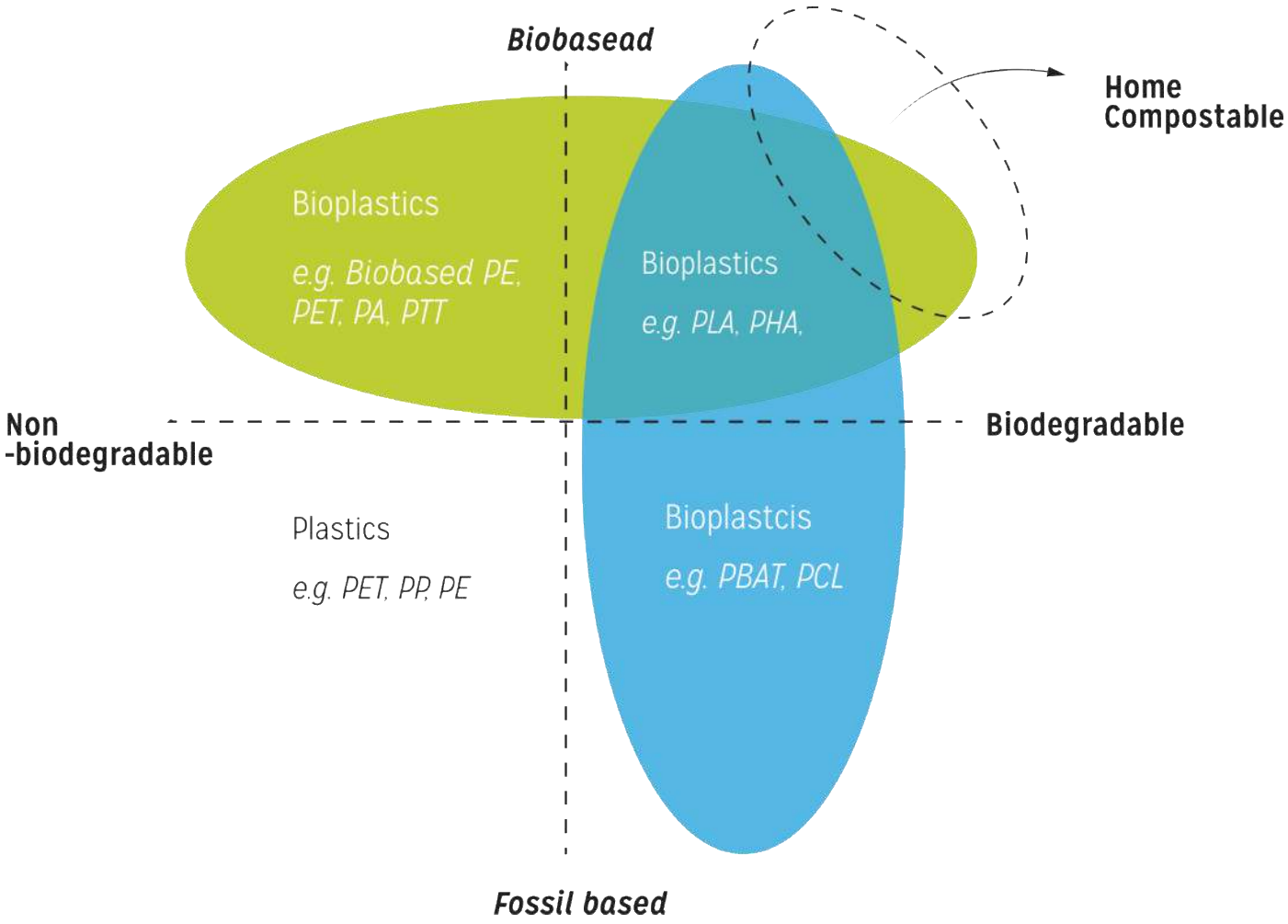


Fig. 8: **Plastics Diagram** – adapted from European Bioplastics, 2015

Circular Design

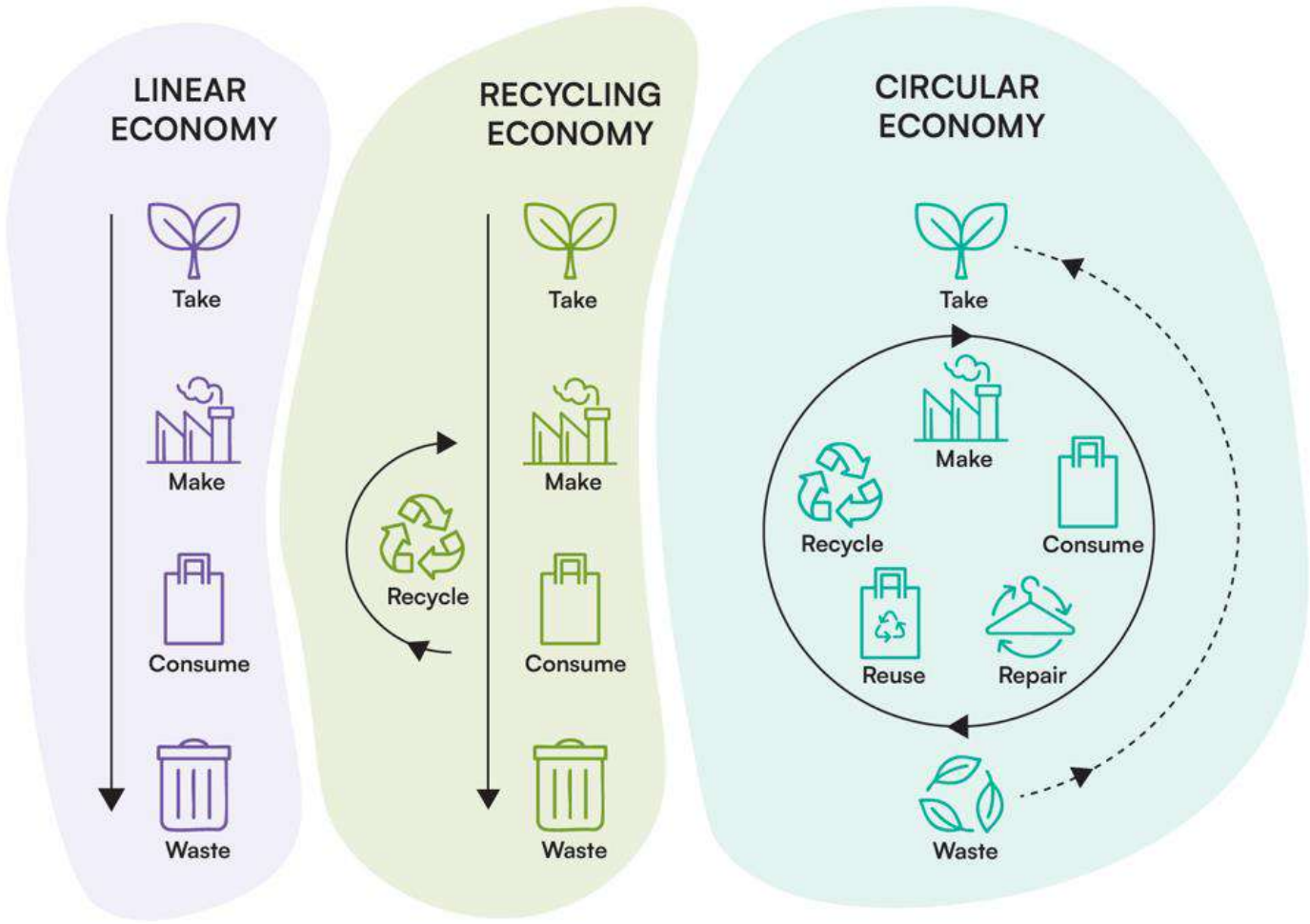


Fig. 9: **Economy from linear to circular Scheme** – adapted from Ellen MacArthur Foundation (2013)



Bio-based Materials

Bio-Materials or Bio-based Materials?

- **Bio-Materials**
  are substances or mixtures of substances, **natural or artificial**,
  that **act partially on biological systems** or to replace, augment or treat them (e.g. prostheses, implants, contact lenses)

- **Bio-based Materials**
  are all materials of **natural origin, organic or non-organic**.

(Stasiškienė et al., 2022)

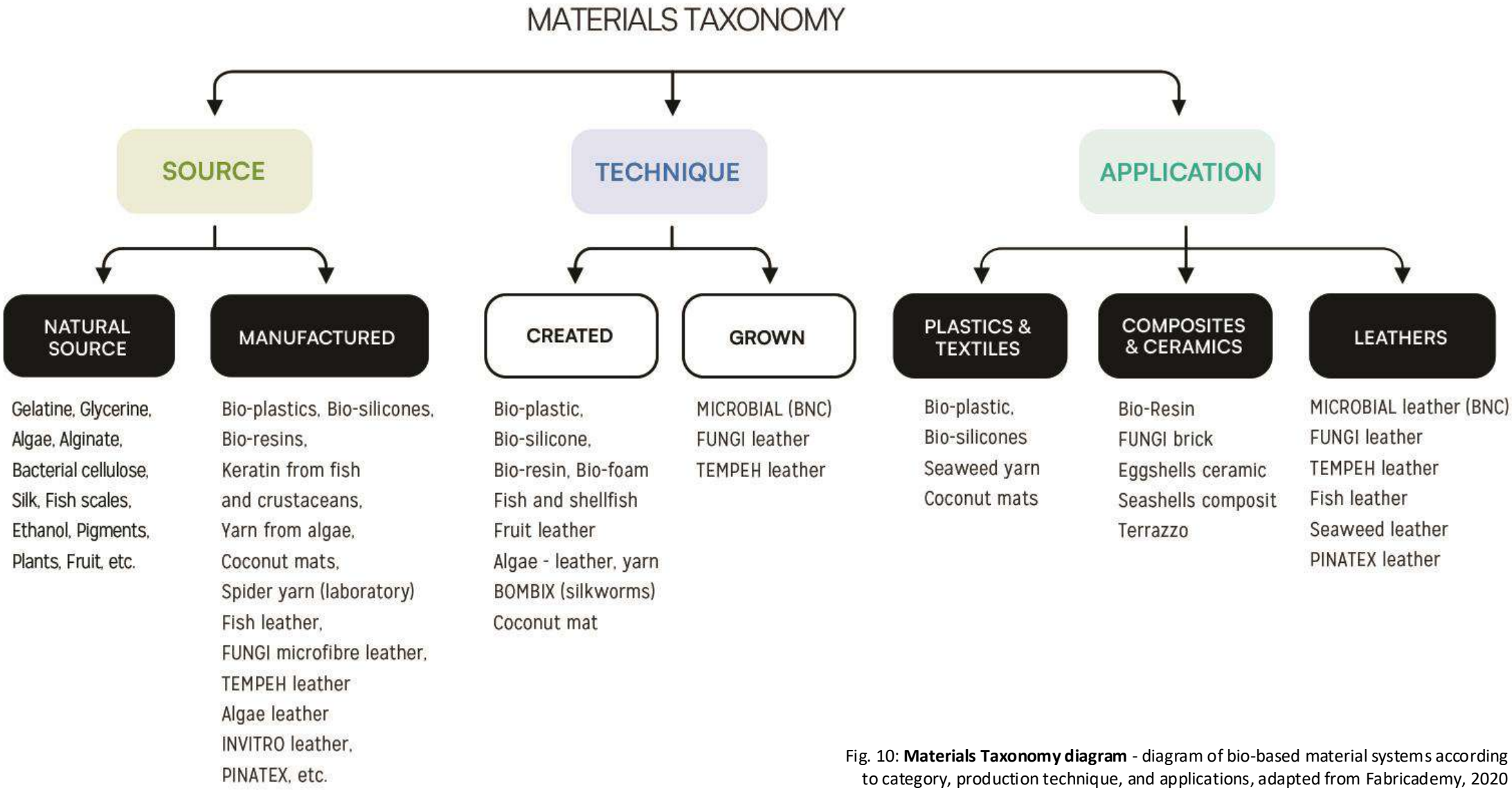


Fig. 10: **Materials Taxonomy diagram** - diagram of bio-based material systems according to category, production technique, and applications, adapted from Fabricademy, 2020

Gelatine

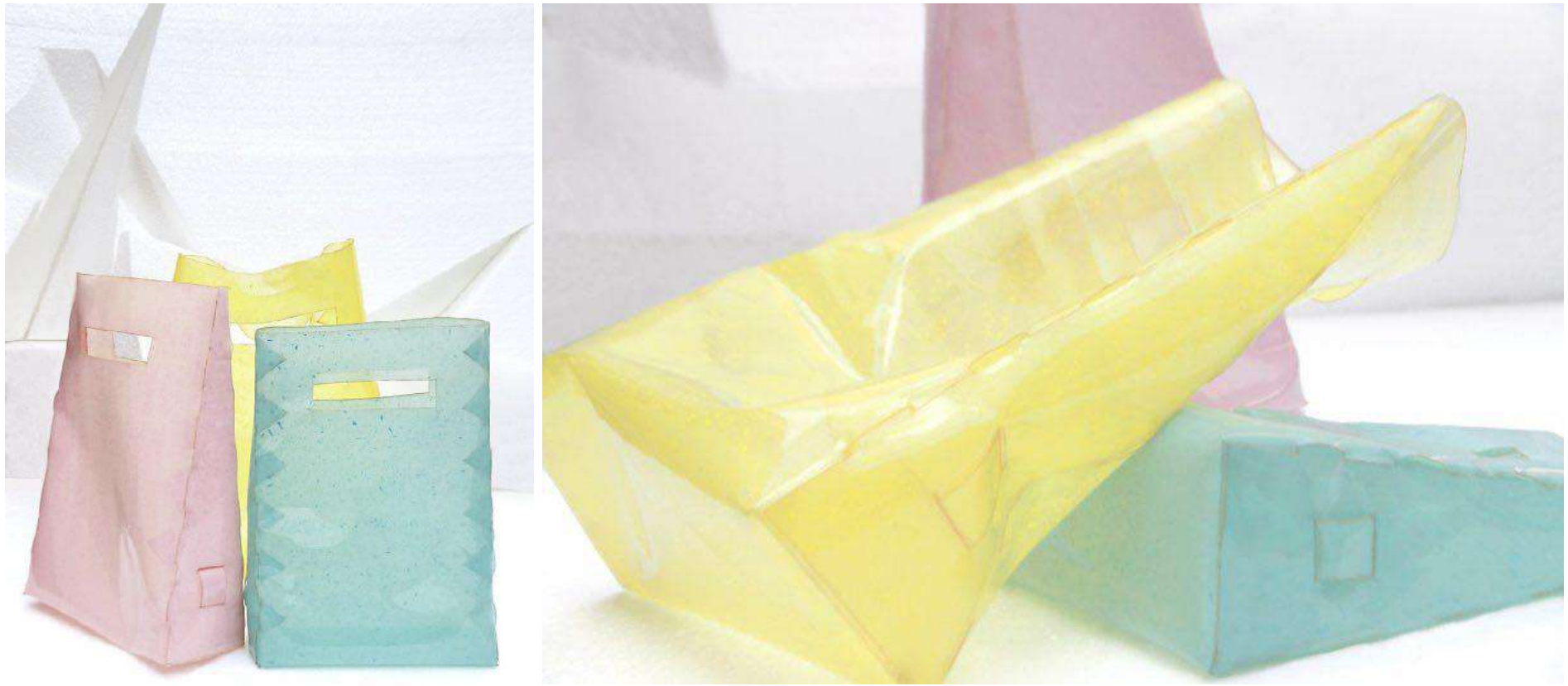


Fig. 11, 12: **Bioplastic Laser cut bags** – Clara Davis, FABTEXTILES, 2017

Agar





Fig. 13, 14: **Agar Beads Bioplastics** – Carolyn Raff, 2019, retrieved from https://www.materialsource.co.uk/carolyn-raff-on-biomaterials-sustainable-manufacturing-and-baking-sequins/

Alginate



Fig. 15: **Alginate Top Bioplastics** – Margarita Follert, 2019

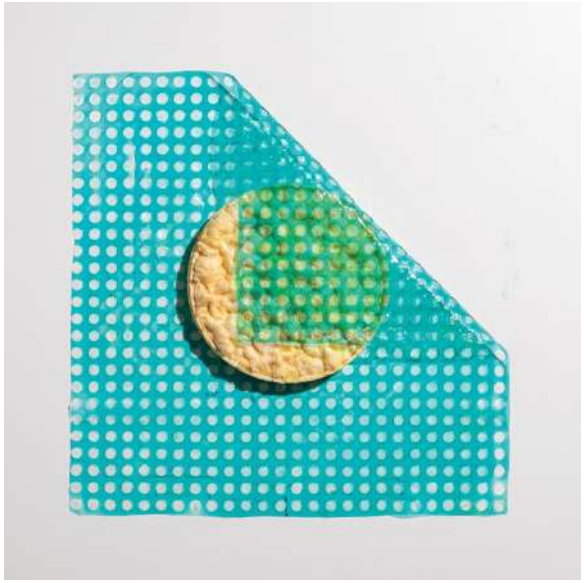




Fig. 16, 17: **Alginate Bio-film with food colours** – Carolina Delgado, 2020

PHA

Polyhydroxyalkanoates are polyesters produced in nature by numerous microorganisms (*poli-hidroácidos*)



Fig. 18, 19, 20: **Algae Bioplastic 3d Printing Filament** – Studio Eric Klarenbeek & Maartje Dros, 2017

Bacterial leather



Fig. 21, 22: **Microbial Leather Bomber Jacket & Jeans Jacket Dyed With Indigo**, Kombucha – Suzanne Lee, 2011

Fruit leather



Fig. 23: **Fruit Waste Leather** – FruitLeather Rotterdam, 2016

Coffee leather



Fig. 24: **Coffee bag** – Aurorae Bourguignon, FABTEXTILES, 2019

Jellyfish leather



Fig. 25: **100% Jellyfish Leather** – Jurii Kasao (n.d.)
Jelly Fish Skin, Naturally Tanned Dried On 3D Mould

Fish leather







Fig. 26, 27, 28: **Fish Leather Stool** – Nienke Hoogvliet, 2015
Salmon Skin, Naturally Tanned On Metal



Fig. 29: **Fish Leather** – Maria Hees,
Carp Leather Dyed And Naturally Tanned

Seaweed

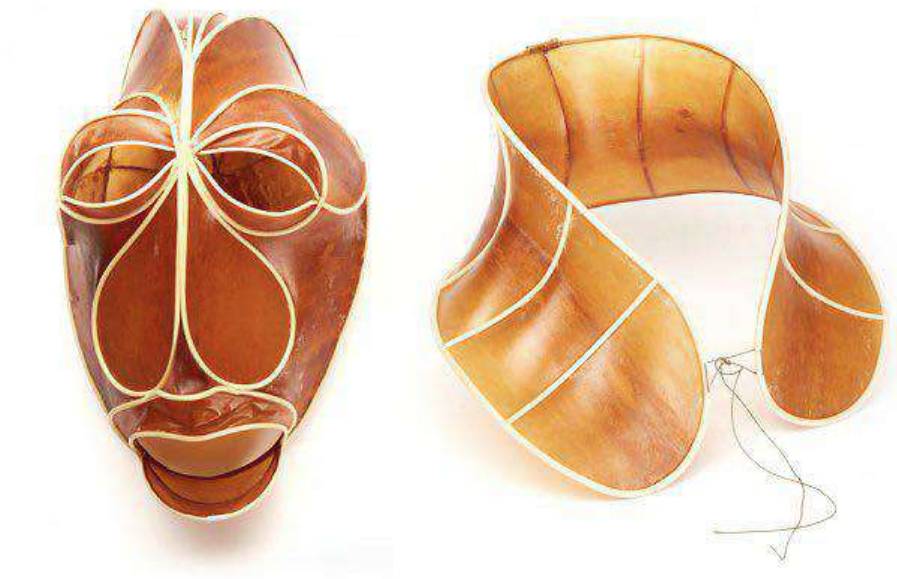


Fig. 30, 31: **Algae Leather** – Julia Lohmann, 2013



Fig. 32: **Sea Me Collection** – Studio Nienke Hoogvliet, 2016

Chitosan



Fig. 33: **Shellworks**, Crab shell Chitosan Plastic – ED Jones, Insiya Jafferjee, Amir Afshar and Andrew Edwards, 2019

Eggshells ceramic







Fig. 34, 35, 36: **Bioceramics**, eggshells and brown algae – Cynthia Nudel, 2023

Seashells composite



Fig. 37: **Self-Reinforced Sea-Shell Composite** – Daniel Batty, n.d., Materiom.com

Fruit and vegetable peels composite







Fig. 38, 39, 40: **Organic Waste** – Cascara Collective, 2018, photo by Tania Malréchauffé

Spider silk



Fig. 41: **Madagascar Spider silk cape** – Simon Peers & Nicholas Godley, 2012



Fig. 42: **BioSteel® Sneakers** – AMSilk and Adidas, 2016

Human Hair



Fig. 43: **The Swing** – Sara Visser, 2017,
Human hair rope



Fig. 44: **Human Material Loop** – Studio Zsofia Kollar, 2021

Mycelium leather & brick





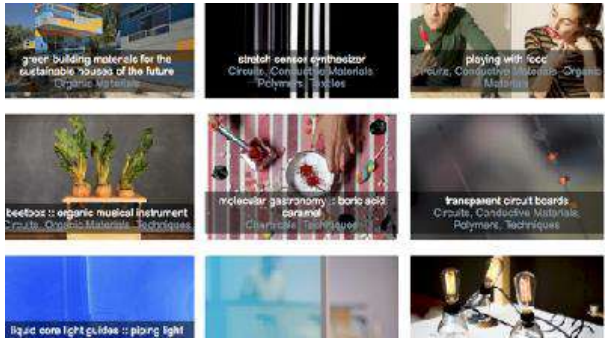


Fig. 45, 46, 47: **The Growing Lab / Mycelia** – Officina Corpuscoli, Maurizio Montalti,
Mycelium leather bag, bowl and chair

Materials Libraries



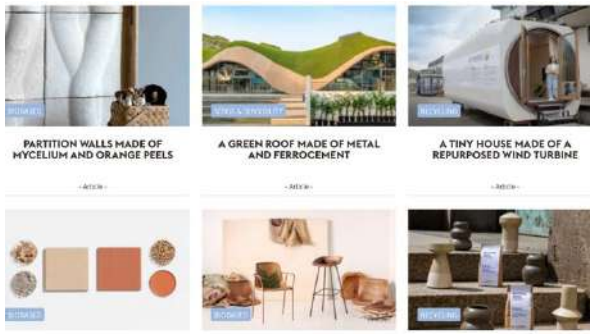
MateriO'
www.materio.com



OPEN Materials
www.openmaterials.org



DIY Materials
www.diy-materials.com



Material District
www.materialdistrict.com



Circular Material Library
www.circularmateriallibrary.org

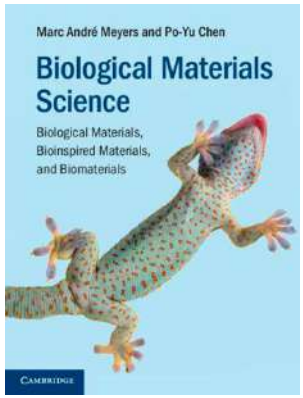


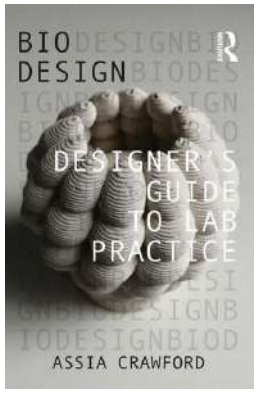
Surface Matter
www.surfacematter.co.uk

Resources

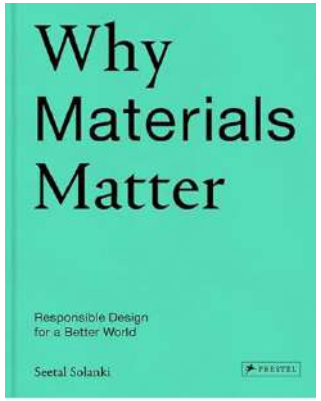


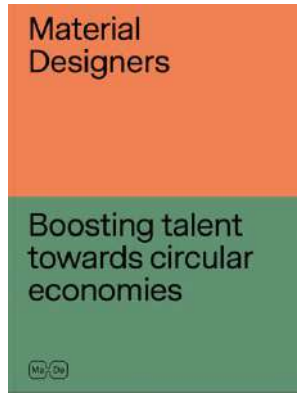


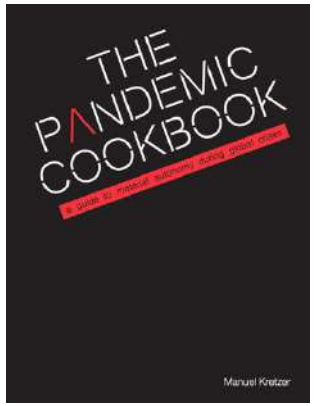


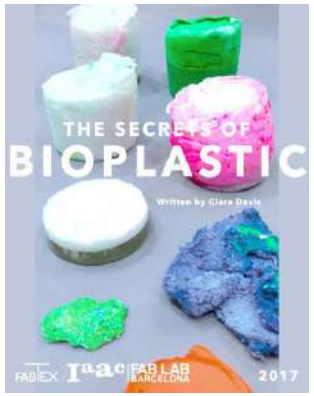


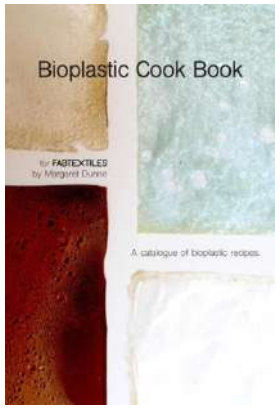




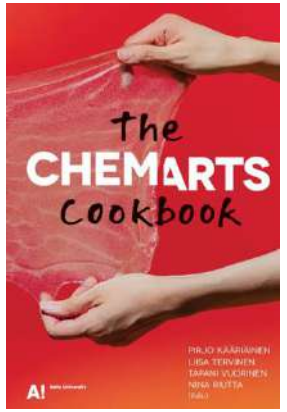


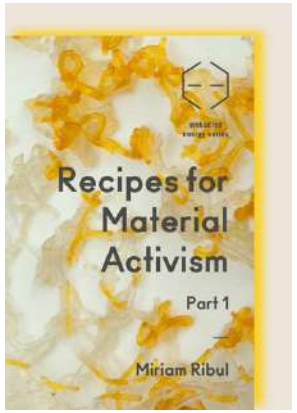


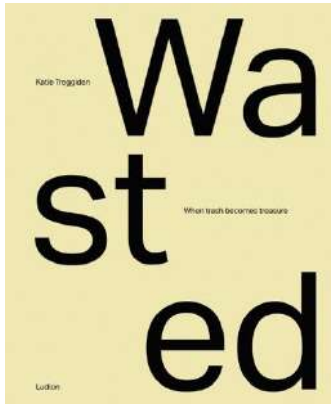












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Thank you!

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IFIMUP Institute of Physics for Advanced Materials, Nanotechnology and Photonics
fct Fundação para a Ciência e a Tecnologia